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ORGANIC PHYSICS.

BY CHARLES MORRIS.

I. THE CHEMICAL EVOLUTION OF LIFE.

IN regard to the question of the origin and character of organic energy the whole course of modern science leads steadily to one conclusion. This is, to express it plainly, that the formation of the organic body is a chemical problem, and the source of life force a question in physics. There has been a severe battle fought against this tendency to reduce life to a chemical equation. The adherents of the doctrine of vital energy have entrenched themselves behind many successive lines of defence, and are still fighting, with the bitterness of despair, behind their last barrier, that of protoplasm. Yet science has gone steadily on, breaking down, one by one, the dividing walls between organic and inorganic nature. Chemical experiment has shown that many of the organic compounds can be reproduced directly from their elements, by processes identical with or parallel to those which nature employs. Others, not yet reproduced, have been analyzed, and the character and mode of union of their constituents shown. The whole vast array of the lower organic compounds has been brought fairly within the field of chemistry, and laid out in definite formulæ. In this respect there no longer exists any organic chemistry. It is simply the chemistry of carbon compounds.

In like manner physical science has taken hold of the forces of living bodies, and has arrived at a similar conclusion. These forces seem to closely accord in degree with the energy that should arise from the quantity of oxidized products yielded. Oxidation must set free energy. This energy must manifest itself as some mode of motion. And if the energy really manifested in the body closely agrees with that which must arise from the oxidation performed, there is nothing left, in this direction, for vitality to do. Chemistry is visibly at work here, too, and vitality is pushed out of the field of view.

Only one point yet exists upon which any question can be raised, and that is the synthesis of protoplasm, or rather of the molecules of which it is made up. There is no question about its analysis. This is admissibly chemical. Oxygen is constantly at work reducing it to its elements. But this oxidation does not suddenly break it asunder into elementary particles. On the con-

trary it takes it apart, piece by piece, as men take down the timbers of a house. Protoplasm has evidently a definite chemical structure, and if it can be taken down piecemeal it can be built up piecemeal. If susceptible to chemical analysis it must be susceptible to chemical synthesis.

Moreover, animal bodies have nothing to do with the production of protoplasm. It is produced in plants alone. Animals simply add new protoplasm derived from plants to their existing protoplasmic tissues. Thus if vitality is confined in its action to the formation of protoplasm, then vitality exists in plants alone, and animals are destitute of it. Or if animals possess vital force its action is confined to assimilation, the causing of one fragment of protoplasm to cohere to another.

Evidently chemistry has driven vitality into a very close corner, and left it a very weak leg to stand upon. And if we give vitality its correct name this leg grows weaker still. It is not chemical or physical energy. It is none of the forces at work in inorganic nature. Therefore it is something supernatural. Its adherents do not claim this. They do not boldly declare what they necessarily imply, that the formation and assimilation of protoplasm are miraculous processes, and that organic existence is only sustained by a continual miracle. But their premises admit of no other conclusion. Yet the duty of miracle in this direction is a very limited one. Chemistry has free possession of the whole field, with the exception of a single obscure corner, in which alone the miracle of vitality tremblingly holds out.

There is a crucial test to which this final question may be put. There is one fixed condition under which alone the activity of protoplasm can display itself. Oxygen must always be present. There is no life without oxygen. When this element is abnormally abundant life proceeds with abnormal rapidity. When it is deficient in quantity life becomes sluggish. When it is prevented from entering the organism life ceases to exist. Hence vitality is incapable of displaying itself except in the presence of oxygen, and the problem becomes the following: so much oxygen, so much vitality. The one is measured in terms of the other.

No one can imagine that the mere presence of oxygen sets the wheels of vitality in motion. Oxygen is too vigorous a chemical agent to rest at ease in contact with the weakly cohering molecules of protoplasm. It cannot but seize upon some of their con-

stituents. That it constantly does so we are well aware, and its vigor in this respect is in close accordance with the vigor of vitality. So much life action is represented by so much chemical action. Chemical waste of the tissues accompanies every exercise of vitality. Yet if vitality be some super-physical process, some miraculous energy by which life is sustained and growth proceeds, why is oxygen so absolutely necessary to its performances? Why does chemical action necessarily accompany it? The more closely we look into the matter the more evident it becomes that there is no such energy in existence as a special vital force, and that chemical affinity is the only energy active in organic processes.

Oxygen is much more than the scavenger of the organic body. It is its quickener. It is the life-giver to which all vitality is due. Its mode of action is undoubtedly destructive. But in destroying old constructions it yields the energy through which alone reconstruction can be effected. It is eating into life with an insatiable appetite, yet in doing so it gives off energies which constantly create new life. In the vegetable world the energy of the solar rays supplies the force necessary to the first step in organic synthesis, but oxygen does all the rest. Two opposite energies are constantly at work—chemical analysis and chemical synthesis—and the former is absolutely necessary to every step of the latter. Oxygen is incessantly engaged in the plant, breaking down its molecules into simpler forms. But in doing so it yields energy which is exercised in the formation of new and more complex molecules. Every step of analysis is followed or accompanied by a step of synthesis. All the energy yielded by oxidation in the plant is thus employed, and step by step organic chemistry advances, until the proteid molecules of protoplasm are finally produced.

In animals the life process does not differ essentially from that of plants. Yet chemically animals begin where plants leave off. The highest chemical product of plants serves as the nutriment of animals. Their principle of action is the same. Every act of chemical synthesis in both is preceded, or accompanied, by an act of analysis. Every step of a portion of matter up stairs is based upon a step of some other portion of matter down stairs. But in animals the process begins near the top of the stairs. Only a few steps can be made upwards; many steps can be made downwards.

Hence the energy set free in analysis is only partly needed for new synthesis. Certain changes perhaps take place in the proteid molecules, but the essential work performed is the assimilation of new material, closely similar to the protoplasm of the tissues. For this labor only a tithe of the energy set free by oxidation is requisite, and the remainder is ready for any other employment to which the organism can devote it. If not otherwise employed it becomes temperature energy, but it is also used in two special methods, as nerve and as muscle energy, and organic development is little more than an increasing specialization of these two modes of energy.

If now we come to seek the method by which assimilation of protoplasm, and growth of structure, is achieved in the animal body, we shall find it not easy to discover. Albumen is such a highly complex substance, and its chemical composition and changes in constitution are so far beyond the present appliances of chemical science, that we can only proceed by the process of analogy, and seek the possible instead of being able to display the actual. We are apt to speak of protoplasm as if it were one undeviating substance. Yet we might as reasonably speak of the several varieties of starch, of sugar, of woody fiber, of gum, etc., as a single substance. They are only variations of one special form of chemical molecule, and that a comparatively simple one. The molecule of albumen is excessively more complex than that of starch, and is therefore capable of an immensely wider series of variations, without essential change of constitution. And the more complex a molecule becomes the less its internal variations affect its physical constitution. Two simple oxides may differ very widely in physical character. Two unlike sugars present very slight differences. Two diverse albumens may present no appreciable difference. For all we know to the contrary not only the proteid molecules of every special animal tissue may have special constitutions, but also those of every diverse species of animal, and, in a minor degree, of every separate individual.

When we speak of protoplasm it is far from certain that we are speaking of a homogeneous substance. A mass of protoplasm is made up of chemical molecules which, even if similar in general constitution, may differ in important particulars. If, indeed, we come down to the basic principle of chemical action, we find it to be a satisfaction of active affinities. This satisfaction may be com-

pleted in a single step and inactivity be immediately produced, or it may require several successive steps, and inactivity be only gradually produced. Molecules in which considerable activity yet exists we denominate as acids or bases, accordingly as they diverge to the negative or positive side in their electric relations. Molecules in which activity has ceased, or has become very slight, we know as salts. If all their affinities are satisfied they are neutral salts. If acid or basic affinities yet exist they are acid or basic salts.

But the inactivity of a neutral salt only refers to its further synthesis. It is still susceptible of analysis. Some of its elementary materials may be taken from it by the affinities of an active element. And this loss of material leaves the molecule again energetic. It has become once more an active radical, and is capable of regaining the materials it has lost, or of taking up new ones. Thus it may form a new molecule more complex than the original one.

These modes of action of inorganic chemism certainly apply to organic chemism, even in its highest stages. Every exercise of affinity satisfies some of the active chemical energy of the molecule, and thus reduces its energies. When these are all satisfied it becomes inactive. It is a neutral salt, incapable of further synthesis, yet still open to analysis. But if we look upon a molecule of protoplasm as an organic salt it is evident that it may have many more bonds of unsatisfied affinity than an inorganic salt. An acid or basic inorganic salt is neutralized after taking up one or two monad atoms. An analogous organic salt may perhaps be able to take up successively ten or twenty monad atoms, or compound radicals.

These considerations are not without their bearing upon the question of the growth of protoplasm. Did the proteid molecule act only by its own chemical energies, evidently its action could not long continue. Although it might begin with many unsatisfied bonds, every new exercise of affinity would decrease its possible action. When all its affinities were satisfied growth must cease, and the molecule become a neutral salt. But though synthesis could proceed no further, analysis might act to again energize the molecule, and the more complex its condition the more subject it must become to analytic action.

Such seems to be the mode of operation in protoplasmic growth.

In fact there could be no other if this growth be a chemical process, for synthesis is a self-checking method and cannot long continue unless its energy be restored by analysis. If a mass of protoplasm be made up of molecules of the same chemical constitution they may yet differ in degree of satisfaction of their affinities, and may be partly neutral, partly basic, and partly acid in their energies. Any exercise of these affinities tends to reduce them all to neutrality, and thus to restrict their chemical action. But they are constantly exposed to the assaults of oxygen, which, at every contact, robs them of some of their constituents, and thus restores their chemical activity. We must certainly deduce some such conclusion as this from the necessity of oxygen to all life energy, and the increase in oxidized waste with every increase in vital activity. Oxidation gives rise to this vital activity, which consists in the restoration of active chemical affinity to the oxidized molecules, and in the reproduction of protoplasmic tissues. Both results arise from one cause. Oxygen robs matter from the proteid molecules, and restores their lost chemical energy. They assimilate new material from the nutrient fluid; while animal motion and temperature arise from the excess of energy yielded by the oxidation.

This general survey of the process leads us to a more particular conception of its character. There is a peculiar polarity concerned in all chemical processes which is of essential importance here. A neutral salt is really a polar arrangement of the elements. Its molecule has its positive and negative poles, but the energy of each restrains and balances that of the other. If we call such a molecule an acid salt, this is equivalent to saying that its acid pole has an excess of energy over its basic. New basic material is drawn in, and the poles become equal in energy, so that all their affinities are exercised internally. But if the constituents of this molecule be separated, their opposite chemical polarities at once become active. The one becomes an energetic base, the other an energetic acid. If this separation proceeds further, a portion of the products of the second separation becomes still more powerfully basic or acid, while other portions may return towards neutrality. If, for illustration, we take a molecule of the powerful acid H_2SO_4 and cause it to combine with two molecules of the equally powerful base NaOH , we obtain the neutral salt Na_2SO_4 , two molecules of water being ejected. A redivision

of this salt into its constituents yields the acid and base above named. The chemical poles, from being passive, have become active. A secondary division of the base gives us Na and OH, a powerful positive element, and a weak negative molecule. If finally OH be separated into its constituents, we obtain an atom of the active negative element, oxygen, and one of the weakly positive element, hydrogen. Analysis of the sulphuric acid molecule yields like results, one of which will be the neutral substance H_2O , or water.

It may here be asked what has all this to do with the chemical activity of protoplasm? It may possibly have much to do with it. If this activity be a chemical one it is certainly governed by the ruling principles and processes of chemistry. There is another chemical mode of action which may also have a bearing upon this question—that concerned in the chemism of the galvanic circuit. In this circuit, as ordinarily constructed, there is but a single chemical energy in active operation, the affinity of the positive metal for the negative element of the fluid. For instance, in an ordinary form of battery, the oxygen of water combines with the metal zinc, the molecules of water interchange their atoms throughout the line of the circuit, and free hydrogen is given off at the surface of the other metal employed. But if this second metal could be replaced by a substance having an affinity for hydrogen, a more vigorous chemical action might take place, with the production of new molecules at each pole. Perhaps such a double action does occasionally take place in the local circuits produced in ordinary chemical action. In the case of such a double action much weaker affinities than those usually employed might suffice.

Yet any such galvanic chemism is necessarily temporary in its action. Its activity diminishes as the analysis of the molecules of the liquid is followed by the formation of new and more stable compounds. There is only one possible method in which we can conceive a constant reinvigoration of its activities, and that is through a continual restoration of its original conditions by reverse chemical action. Could some active atmospheric element, for instance, constantly penetrate the liquid, break down its new formed molecules, and reproduce the original ones, while carrying away the neutralizing constituents, the chemical action of the battery might indefinitely retain its original activity. Its lost en-

ergies would be constantly replaced by energy derived from exterior nature.

Such a continual reinvigoration takes place in organic chemism. The exercise of the affinities of the molecules of protoplasm must constantly tend to reduce their energy, and produce a neutral inactivity. But oxygen comes in, bringing with it the chemical energy of the exterior world. The new-formed, inactive molecules are partly oxidized, and perhaps regain their original condition. The chemical vigor of the circuit is restored, and its activity may thus be ceaseless, since it is continually re-energized by the forces of exterior nature.

As a final deduction from the principles of inorganic chemistry, may be mentioned the fact that the activity of a galvanic circuit in which the affinities of both the positive and the negative constituents of the molecules of the liquid are engaged, must depend upon the vigor of the opposite polarities of the circuit. If either the positive or the negative energy be neutralized the chemical activity must be checked, while if one or both of these polar energies be decreased the activity of the circuit must be similarly reduced.

These principles of inorganic chemism might have been considered in more detail, since there is reason to believe that they are the agencies concerned in the higher organic chemistry. For the sake of brevity they have been given in a very condensed form with little attempt at illustration. It remains to apply them to the phenomena of what is called life action, or the assimilation and growth of protoplasm.

In considering this question we have to deal with the units of organic beings. Not the cell, but the nucleus of the cell, which is undoubtedly the active agent in protoplasmic growth. The nucleus is itself an organized body, and appears to contain other materials than the proteid molecules to whose chemical activity the phenomena of organic life are due. It is also evidently a polar organization, its polarity being markedly displayed at the time of its division. The two nuclei into which the original one divides represents each a polar half of the original nucleus. Thus the probable balanced polarity of the primary cell nucleus becomes an unbalanced polarity in the new cells resulting from its division. We hope to show that this is a fact of essential importance.

The protoplasmic mass which constitutes the nucleus is an aggregation of highly complex chemical molecules similar, perhaps, in constitution, but which may differ considerably in the degree of satisfaction of their affinities. Some may be neutral, some acid, and some basic salts of the same chemical compound. If such be the case we can comprehend the polarity of the nucleus. The arrangement of its molecules may be but an expansion of the principle of arrangement of the polar constituents of a neutral salt molecule. This has its acid and its basic pole; and we can imagine the molecules of the nuclear unit to be similarly arranged, not only with the acid and the basic poles of each turned in opposite directions, but with the molecules of acid affinity occupying one pole, and those of basic affinity the other pole, of the nucleus.

For this to be the case, however, some influencing agency is requisite, such as that of external chemical affinity. In short, the polarity of the nucleus may represent that of a galvanic circuit with active chemical affinity at each pole. The two poles of the nucleus may represent the acid and basic poles of such a circuit, and the nutrient material, the zinc and copper, or whatever other substances are employed. If such be indeed the character of the nuclear polarity we can comprehend various results which are now mysterious to us. The assimilation of nutriment by such a polar arrangement would be a strictly chemical process, the opposite poles taking up respectively basic and acid material. But the activity of this circuit, if dependant upon its own energies alone, must quickly come to an end through the satisfaction of the polar affinities and the chemical neutralization of the molecules.

At this point the agency of oxygen comes in. This energetic element attacks and partly breaks down the complex proteid molecules, and restores to them their lost affinities. Through its action the original activity of these molecules is regained, and they again vigorously attract the chemical radicals of the nutriment. Thus the probably small quantity of material carried off by every act of oxidation is perhaps replaced by the assimilation of larger and more complex molecules from the nutriment, and the protoplasmic mass grows in consequence.

This, of course, is all pure hypothesis. We are ignorant of, and perhaps may always remain ignorant of the facts that would

prove or disprove it. Yet we have no reason to doubt that the assimilation of nutriment is a chemical process; we know that the nucleus is a polar organization, we know that oxidation is essential to its activity, and that the chemical relations here supposed are in accordance with those that exist, or might possibly exist, in the active liquid of the galvanic battery. Thus the basis of the hypothesis is not unreasonable; and it may be shown that certain of its necessary results are strikingly in accordance with some of the most abstruse phenomena of organic life. If the hypothesis here advanced should prove a key to unlock the mystery of these phenomena, and the organic unit have in its chemical organization the essential elements of the most specialized life conditions, our hypothesis will certainly become worthy of consideration.

For such a polar arrangement of acid and basic molecules to be fully effective, it seems necessary that each pole should be in full vigor. Their energies mutually support and aid each other. Any check to the action of the basic pole, for instance, would check that of the acid pole. The chemical activity of the one is rendered possible by the chemical activity of the other, and there may take place an interchange of the constituents of the molecules like that supposed to occur in the water molecules of the battery. Hence the chemical activity of the nucleus would be controlled by that of its least vigorous pole, and for its fullest activity the poles must be equal in energy, and this energy be raised to its highest level of vigor.

As for the aid of oxygen in the process, it is not probable that the oxidation is an immediate accompaniment of the chemical action. Oxygen is constantly making its way into the organic cells, and it is probable that a slow oxidation continually goes on, its quantity depending upon the vascularity of the organ concerned. Under special circumstances, as of irritation of the nervous and muscular tissues, oxidation seems to become suddenly invigorated, and a considerable breaking down of the organic molecules takes place, with a vigorous discharge of energy. But every act of oxidation puts the nuclear molecules in a condition for active chemical assimilation, so that if the requisite nutrient material is provided, the loss is quickly repaired, and new proteid molecules, specially sensitive to the affinity of oxygen are produced. And so the wheels of life roll on, and growth replaces waste.

It might seem as if in such a process we had a provision for an endless life activity. The chemical energy of protoplasm, constantly quickened as it is by oxidation, appears capable of yielding an indefinitely large mass of material, so that the bulk and length of life of organisms might have no limits. Yet we are well aware that no such results take place, and therefore must believe that they are impossible. There must be some principle that checks both an indefinite increase in bulk and a ceaseless continuance of life.

There is such a principle, and the first step of its action is a check to indefinite growth of the nuclear unit. For the activity of this growth free access both of nutriment and of oxygen is necessary. But the oxidation to which growth is due quickly interposes a check to its activity. Some of the waste materials yielded by oxidation appear to remain within the nucleus. Others collect around it and form a mass which is known as the organic cell, of which the nucleus occupies the center. Evidently this process must oppose that of nuclear growth. With every exercise of chemical activity the mass of "formed material" around the nucleus increases in bulk, the access of oxygen and of nutriment is more and more hindered, and the nuclear energy is checked.¹

There is only one method by which it can be regained. The waste material continues to cling firmly around it, and only by division of the mass into smaller portions can its nuclear center regain its former relations with the nutriment. This division takes place, and always through the nucleus. It might be imagined, indeed, that a vigorous effort was made by the polar constituents of the nucleus to reach the attractive nutriment, since division is always preceded by a strongly declared polar arrangement of its material, and it separates at its equator, its two original poles becoming the nuclear centers of two new cells. Growth energy is regained in these new cells, but its vigor is decreased with every successive division, for a reason now to be given.

¹ Part of the waste material is carried away by the nutritive current, and we can readily conceive of a condition in which all the waste is carried away, and the protoplasm left fully free to act. But such a condition is inconsistent with any high degree of organic development. Active protoplasm is necessarily semi-fluid in consistency. The retention of waste material is necessary to give consistency to the organism, and permit its increase in size and its organic differentiation. Some Protozoans are nearly pure protoplasm, but evolution in this direction must be soon checked by lack of solidity. For any extended development the protoplasm of the cell must retain around it some of its devitalized waste.

The ideas here advanced as to the constitution of the organic unit are not mere baseless supposition. This unit must be composed of chemical molecules, either identical or diverse in character. Their chemical activity seems to render a diversity more probable than an identity; but the apparent homogeneity of each unit seems to indicate that its molecules are not diverse in their chemical constitution, but only in their degree of chemical satisfaction. They must be either acid, basic or neutral in character, and very probably divergences in this respect occur between the molecules of every unit mass. But in mixtures of acid, basic and neutral molecules there might be great variations; here the acid, there the basic energy might be in excess. In other cases there might be a balance between these energies. Probably all these variations exist in organic units. Yet for the reasons we have here given, it seems probable that the unit mass in which the energies of the acid and basic molecules were balanced, would be best constituted for vigorous chemical action; and particularly so if these acid and basic energies diverged considerably from the neutral line. Such we conceive to be the constitution of a fully active chemical unit. But the process of cell division tends to diminish this activity.

For the separation of a nucleus into two halves, through its neutral equatorial region, must leave one of these halves with an excess of acid over basic vigor, and the other with an excess of basic over acid. The full energy of the acid pole remains in the one, in combination with a basic pole of reduced energy; and the same rule applies to the basic pole of the other. Thus the chemical energy of each must be less than that of the original unit. A second division adds to this effect. Of the acid half, for instance, after re-division in one of the new cells, the energy of the acid pole would be retained, with a basic pole still further diminished in energy; while in the other the two poles would return towards equality, but with diminished energy. This division must constantly tend to reduce the chemical energy of the cells.

A formula may aid in the elucidation of this principle. Suppose A——B stands for a normal unit, A and B representing the most vigorous acid and basic molecules, while the connecting line represents a mass of molecules becoming successively less strongly acid and basic, until neutrality is attained at the

equator of the mass. If now this unit be divided equatorially we obtain two new units, A——B and A——B. Their chemical energy is decreased, because each has a weakened pole. A division of the first of these new units will give us A——b and a——B. Here the first is thrown still more out of polar balance, while the second regains equality, but with diminished energy. And so on with continued division. We would obtain as the extreme terms of the process two cells, in one of which the full acid was accompanied by a greatly reduced basic vigor, and in the other a like advantage would be gained by the basic pole. Between these would be a succession of cells, less out of chemical balance, with one or more intermediate cells in which the balance of energy would be preserved. But in all these cells the vigor of one or both of the poles would be greatly reduced, so that the chemical activity must decline in vigor with every new act of division. Such a result is but an organic example of the principle we have already considered in inorganic nature, in the gradual separation of the constituents of sodium sulphate, Na_2SO_4 . The molecules of the original cell would be represented by the mass of new cells into which it finally breaks up, some of these cells being specially acid, basic or neutral, as were the molecules of the normal cell.

In such a process we see the original strongly declared heterogeneity of the normal unit gradually diminishing, and chemical homogeneity approaching, while life vigor decreases in accordance. The process of division, which is necessary to keep up the activity of the cell, inevitably tends to diminish this activity from a secondary cause, that of loss of chemical heterogeneity. How shall this essential condition be restored, and the full activity of life action be reproduced? Evidently by a reversal of the process above considered. If cell division reduces the life energy, cell combination may restore it. If, for instance, the two extreme terms of such a continued division be reunited, all the lost chemical heterogeneity would be regained, and the normal condition reproduced. Let the two extreme units, A——b and a——B, join to form a new unit; we would have as result A——B, the intermediate polarities falling into place between these polar extremes. Thus by a single process of combination a cell would be gained possessing all the chemical heterogeneity, the polar balance and the vital activity of the original.

And such a result must very strongly tend to occur, from the vigorous attraction between acid and basic chemical radicals. Many other unions might take place, between the remaining cells of the continued division. Thus the final result of the division of a single normal cell, would be the reproduction, from the union of its many daughter cells, of numerous normal cells, differing perhaps considerably in their degree of homogeneity, and in the completeness of their polar balance, yet each capable of setting up a new life cycle.

If now we give this polarity another name, and call it sexual polarity, new light may be thrown upon the life problem. Life is continuous, but not in the individual. The individual tends towards chemical inertness and final death. The continuity of life exists only in the race; and such, under our hypothesis, must be the law governing the development of the organic life units. Division, which is their only available method of continued growth, brings them more and more towards chemical inertness and loss of vitality. Reunion of oppositely polarized germs, which have arisen from the original individual, restores the life activity by the production of a new vitalized individual. The life energy, failing in the individual, is restored in the race.

If we replace the words acid and basic polarity by male and female polarity, the cycle of life opens out before us. A normal unit or germ possesses balanced male and female energies. Continued division produces a multitude of new cells, some with an excess of male, some of female energy. As either energy weakens, the life energy of the new unit weakens. Each of these cells is a male or a female germ. The union of two of opposite sex produces a fertilized germ, in which the balance of male and female energies is restored, and which is, therefore, capable of setting up a new cycle of development. All that we know of the life development of Protozoan animals is in accordance with this hypothesis. And evidently, if the sexual polarities were balanced in the original Protozoan, they must be balanced in all its descendants taken as a whole; so that the degree of opposite polarities, and the numbers of each sex, must continue equal. And as in the reunion of germs, it is highly improbable that out of the vast numbers produced, two of exactly balanced sexual polarity should meet, therefore the new individuals are very likely to be specially male or female in condition, possessing some excess of acid or basic energy in their chemical organization.

[*To be continued.*]